QCEA environmental fact sheets

An Introduction to domestic Solar Photovoltaic (PV) Panels

In this paper:

Introduction

- Photovoltaic (PV) panels are solar panels that convert sunlight directly into electricity. This needs to be distinguished from thermal solar panels which are used to heat water. The issues discussed in this paper are specific to PV.

- The EU Renewable Energy Directive states that 20% of the EU's energy must be produced through renewables by 2020[1]. The EU PV markets have grown at an average of 35% over the last 5 years[2]. This growth rate, however impressive it may be, is not fast enough to contribute significantly to the EU renewables target as it is still only around 1.5 % of total energy production.

- PV is often looked at in terms of a cost-benefit analysis without sufficient emphasis upon the environmental considerations. Although the economics of PV panels play a significant part in an individual's decision, environmental arguments should not be neglected.

- Two main issues that affect PV from an environmental perspective are the energy it requires to construct them and whether rare and/or dangerous semi-conducting materials are used in their production.

This paper aims to provide an introduction to the main issues around PV to help consumers make an informed decision about PV for domestic use.

---

[1] An overview on how to achieve this is available at http://ec.europa.eu/energy/renewables.

[2] http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_pv/article_1265_en.htm.

1. Energy payback time:

In a nutshell:
A general payback period is estimated to be about 1-4 years for southern and middle European countries and 4-8 years for the northern reaches of Scotland. The normal life-span for a PV panel with current technology is approximately 25-30 years. Thus, even in the most unfavourable circumstances PV panels still produce at least 3 times the energy that it takes to make them.

1.1 What is an energy payback time and how can it be assessed?

The energy payback time is the time it takes for any kind of energy producing installation to produce the amount of energy that it took to construct it. This should not be confused with an economic payback time which assesses the time in which the cost to the householder is compensated by the earnings from the production of electricity at home. In order to calculate the energy payback time a so-called life cycle assessment (LCA) has proven very useful. This "cradle-to-grave analysis" is a framework for describing the lifespan environmental impacts of material and energy inputs and outputs of a product or process. Especially LCAs of new energy technologies are increasingly used in decisions about energy policies and funding for research and development. In 2008 the European Commission provided the conditions for generating up-to-date LCAs under the *European CrystalClear Project*[3].

The holistic approach of LCAs includes all the resources that go into the production, operation and disposal of a PV system. The resulting emissions that arise from using fossil-fuel-based energy to produce the materials for solar cells, modules, and systems, as well as those emitted directly from smelting, production, and manufacturing facilities, are both taken into account to measure the environmental impact.

However, it needs to be pointed out that today's assessments are based on existing data which is by nature a few years old. The latest facilities have even lower energy consumption and it can be assumed that this tendency is going to continue and that today's best technology will soon become the standard[4].

1.2 Estimates

Numerous detailed studies have been conducted in the last decade on the issue of energy payback times of different PV panels with very varying outcomes between 0.7 and 22 years.[5] This is a result of different factors being taken into account, different assumptions on which the studies were based, and different panel models. However, the individual payback time of any common solar panel mainly depends on a combination of a few core factors: geographic situation, type of the panel as well as the roof gradient and orientation.

---

[3] More about the *European CrystalClear Project* at: http://www.ipcrystalclear.info.
[4] http://www.bnl.gov/pv/files/pdf/abs_193.pdf.
[5] An overview can be found at: http://www.energybulletin.net/node/17219.

In the very south of Europe a panel will receive approximately 1700 kilowatt hours per square metre per year ($kWh/m^2/a$).[6] Following the majority of recent studies, a standard crystalline silicon (c-SI) panel put to use in this area will create the amount of energy it took to produce it in 1-3 years. With a minimum life expectancy of 25 years for such a panel, it will hence create energy without any CO_2 emissions attached to its production for between 22 and 24 years. Generally, the less $kWh/m^2/a$ the panel receives, the longer is the payback time. With a c-SI panel placed in the north of England receiving about 900 $kWh/m^2/a$, there would still be a gain of at least 17 years of clean energy production.

The actual saving of CO_2 through the installation of a PV panel varies from country to country, depending on the specific electricity mix and therefore depending on the kind of electricity that would otherwise have been used. Roughly, a normal installation with 1.5 kilowatt peak (kWp - the peak output) on a south facing roof in the UK for example will produce a third of an average family's electricity demand. Annually, this would amount to savings of about half a ton of CO_2.[7]

1.3 Recycling

The first generation of PV panels are starting to come to the end of their life. However, the silicon used in most PV panels can be recycled. This will significantly reduce the amount of energy needed to produce panels of the second generation as it removes some of the most carbon intensive stages of production. It is not only possible to recycle the expensive cells within a PV panel, but it is also possible to recycle the aluminium frames, glass and cables. There are organisations already set up such as the Belgium-based association PV Cycle, who brings together a variety of European solar manufactures and retailers. Their aim is 'to promote protection of the climate and the environment' by implementing 'an overall waste management and recycling policy for the industry'.[8] At the moment PV Cycle estimates that 85 % of a c-SI module can be recycled. By taking advantage of the opportunities of PV cell recycling, second generation panels will require less energy during their production than first generation ones.

2. Rare and/or dangerous materials

In a nutshell:
It has become widely accepted among experts that concerns about the environmental impacts from materials involved in PV construction are overrated and unfounded. They are negligible in industrial applications and insignificant in domestic ones. On top of that the last decade saw promising changes in many parameters not only in c-Si feedstock production and wafer sawing but also in in-house silicon recycling.

A key question to working out the sustainability of the PV industry is: what raw materials are actually needed for the production of PV? Here it needs to be said that the more problematic

---

[6] For a more detailed overview see chapter 3.1.1.

[7] Assuming a 10 kWh average per year.

[8] http://www.pvcycle.org.

materials are to be found overwhelmingly in certain thin-film technologies which are currently used more commonly in industrial applications and not in domestic panels. Most domestic panels will be c-SI panels.

2. 1 Materials found in domestic applications:

Silicon

Silicon is the second most abundant element in the earth's crust after oxygen and hence there is no shortage of it. Despite this, there have been shortages of processed high grade silicon which has caused significant price fluctuations. This has more to do with manufacturing capacity than natural supplies. Higher demand will bring down the production cost of silicon and also stabilise the market. There are no immediate safety concerns related to domestic silicon PV panels.

2. 2 Materials predominantly found in certain thin-film panels in industrial applications:[9]

Tellurium

Tellurium is a by-product of copper refining. It is rarer than silver, however, there is no shortage yet. Tellurium is used in cadmium tellurium (CdTe) thin-film panels which have achieved some of the best efficiency rates among PV panels. Therefore this sector of the market is likely to increase and it is unclear if the supply of tellurium will be able to meet such increased demand. There are no apparent safety concerns with tellurium.

Cadmium

It is unclear at this stage whether cadmium faces any supply issues. It is a toxic material used to make up CdTe thin film panels cells. However, PV uses only a tiny fraction of all cadmium used, its main consumer being flat screen televisions. To put this into perspective, the amount of cadmium within a typical 1m^2 PV panel is similar to that used in a small battery. Cadmium inside PV panels is in a stable chemical state and poses little health risk if correctly managed. Main concerns for the use in PV arise in the case of fires.

Indium

Indium is a by-product of electrifying zinc and is about as rare as silver. It is however, in high demand from the growing flat screen TV market. Nanomarkets, an electronics research firm, suggest that if the PV industry grows as predicted, then it will consume about 125 tons a year by 2012. The US Geological Survey admits that exact data on global reserves are hard to come by because of the varying parts per million that can be found in base metals (between 1 and 100 parts per million in metals such as zinc, copper, lead and tin). Nevertheless, there appears to be widespread confidence that we do not face a shortage in the supply of indium. Also, there do not appear to be any safety concerns connected with its usage.

---

[9] Information provided by Nanomarkets: http://www.nanomarkets.net and US Geological Survey: http://www.usgs.gov.

3. How much will it cost to install a PV panel for my house?

In a nutshell:
Although prices have gone down significantly over the past few years the costs of a PV panel is still the biggest barrier to installation. In countries with a wide range of incentives such as feed-in tariffs, grants and loans on the one hand and high energy prices on the other hand, the economic payback time can be as little as 8-10 years. Otherwise it may take 15-20 years until installation costs are recovered.

3.1 Cost factors to be considered

- Geographical conditions
- Price of purchasing a whole PV system
- Availability of grants
- Rate of feed-in tariff
- Savings

There are a number of grants, loans, tax credits and subsidies available across EU Member States. It is often dependent upon the specific district or region in which the grant is applied for.

3.1.1 Efficiency of the panel based on geographic situation and the roof characteristics

As mentioned before, a crucial factor in the whole equation is the amount of kWh per square metre per year the panel would receive. Here is an overview of kWh/m²/a throughout Europe:[10]

< 1050 kWh/m²a	Belgium, Denmark, Estonia, Finland, Germany (North), Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, Sweden, UK
1050 - 1200 kWh/m²a	Austria, Czech Republic, France (North), Germany (South), Slovakia, Slovenia, Switzerland, UK (very South)
1200 - 1400 kWh/m²a	Bosnia, Bulgaria, Croatia, France (Centre), FYROM, Hungary, Italy (North), Romania, Serbia
1400 - 1600 kWh/m²a	Albania, France (South), Greece, Italy (Centre), Portugal, Spain
1600 - 1750 kWh/m²a	Portugal (South), Spain (South), Italy (South)

Apart from solar irradiation the characteristics of the roof are also important. The optimum gradient is between 25 – 35°. A roof facing south gets the most energy but southwest and southeast facing roofs also deliver respectable results. Southwest facing roofs should be given priority over southeast facing ones as they will experience less fog. A deviation from a

---

[10] The overview for Europe can be found at http://www.helpsavetheclimate.com/insoleurope.html. A more detailed overview just for the UK can be found at http://www.helpsavetheclimate.com/insoluk.html.

directly south-facing position by up to 50 ° - which would result in 5-10 % less productivity - is acceptable. Generally, the greater the deviation from the optimum south position the steeper a gradient is needed to compensate.


© Wayne National Forest

3.1.2 Price of Purchasing a PV system

The purchase price of a PV system will firstly depend on the price of the panel itself which is between 3500 and 7300 € per 1 kWp and varies according to country and company. Secondly it depends on the cost of the actual installation which will vary on the basis of the technical conditions of the building concerned and will probably be around 500 € per 1 kWp.[11]

3.1.3 Availability of Grants and other support mechanisms

Clearly, where there are government incentives, be it grants or tax reliefs, initial installation becomes less expensive. Other support mechanisms might include targeted bank loans for the installation of PV technology. Again, there is wide variation in the support mechanisms available in different countries and the level of government at which they are accessed (national, regional, local) will also vary.

3.1.4 Feed-in tariffs

The economic feasibility of individuals investing in domestic PV panels depends on whether a country has feed-in tariffs and at what rate these tariffs are set. Feed-in tariffs are guaranteed prices or premiums set by the government for electricity produced from renewable sources paid to the supplier. This provides an incentive for small scale renewable production of electricity. The countries that currently operate a feed-in tariff system are: Austria, Czech Republic, Cyprus, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Latvia, Lithuania, Luxemburg, Portugal, Slovenia, and Spain. In the UK tariffs are due to be introduced by April 2010. It should also be noted that Belgium, Denmark, Italy, Poland, and Sweden all provide incentives to use renewable energy.

3.1.5 Savings

Another economic factor is the saving made by households from the energy they generate themselves, i.e. the cost they would have had to pay for that energy if purchased from an electricity supplier. This depends of course on the energy prices of the particular supplier.

---

[11] For example, see: http://en.wikipedia.org/wiki/Photovoltaics#Photovoltaic_industry_associations where a number of industry associations from a number of different countries and regions are listed.

3.2 Examples

3.2.1 An example from the UK

The following is a worked example based on experience from Stroud (UK):
The calculations are based on a normal 1.5 kWp system with a generating capacity of about 1300 kWh per year. There is a low carbon building grant of 2500 £ and a grant from the district council of 1000 £. The feed-in tariff is 31 pence per kWh. The calculation assumes that half of the electricity is used by the household and half is sold back to the National Grid. For the electricity used by the household, there is a gain of 13 pence per kWh which is the cost of purchasing this from the electricity supplier. The electricity exported to the National Grid generates about 31 pence per kWh. In the UK feed-in tariffs are paid regardless of whether the energy is sold or used by the household itself.[12]

Item	Calculation	Total in £
System cost of a 1kWp panel		9800
Low Carbon Building Grant		-2500
District Council Grant		-1000
Total net cost of system		= 6300

Energy generated	1300 kWh (per year)	
Price of electricity saved	650 kWh at 13 pence	85
Feed-in tariff for sold and used energy	1300 kWh at 31 pence	+ 403
Total income and savings, i.e. value of system per year		= 488

Repayment of system cost to householder	6300/488	= 13 years

We can see that in this example in the UK the system has an economic payback time of approximately 13 years. This is dependent upon receiving a low carbon building grant which will cease to be available from April 2010. It also already incorporates the *clean energy cash back scheme*, which has been presented by the UK government in June 2009. It is expected to begin in early April 2010 and will include a guaranteed tariff rate for PV generators for the next 25 years. Currently the grants are still available so by planning carefully one could take advantage of the new and the old incentives at the same time.

3.2.2 An example from Germany

Germany is one of the countries where the government encourages solar investments the most. Already in 1999 the Red-Green coalition introduced a programme to equip 100 000 roofs with PV technology. Since then, an ever improved legal basis prepared the ground for investors to operate profitably: the law for the promotion of renewable energies (EEG) was amended in 2004 and again in 2009. As a consequence, economic conditions have improved and solar panels have become more and more attractive to consumers. Moreover, it is not only house owners who can produce electricity. Tenants can also participate by joining a collective installation. The German renewable energy law (EEG) is seen as a model for feed-in tariffs and has been adopted by 47 countries so far.

---

[12] http://www.heatmyhome.co.uk/pv-solar-panels.htm.

In the EEG, feed-in tariffs are geared to the year of initial operation. A solar panel installed in 2005 still yields 54.53 cents per delivered kWh whereas one installed in 2010 will only carry a yield of 39.57 cents/kWh. The prices are guaranteed for a time span of twenty years from the date of installation.

The idea behind the legislation is that operators should be given a fixed rate return for the electricity they produce in order to facilitate a quicker payback time. This rate decreases every year in order to give incentives for quick action and an overall reduction in costs. That means the sooner a panel is set up the higher the guaranteed price for the twenty years lifespan.

The solar energy retrievable in Germany varies between 900 kWh/m^2/year in the north and 1200 kWh/m^2/year in the south. A 1.5 kWp installation put on a roof in central Germany would create around 1500 kWh/a. In 2009, the price of panels went down significantly in Germany and now each kWp costs around 3.300 euros. That means you would need to spend about 5000 euros on material and set up of a 1.5 kWp installation, which will be of 12-15 m^2 size. In order to have an initial idea about whether a panel would be a profitable investment in a particular case it is easy to calculate an approximate amount a panel will gain here: http://www.solarserver.de/pvrechner. The equation takes into account the direction and gradient of the roof, the size and efficiency of the panel and the geographic position. Assuming the installation is set up in 2010 and will therefore get a feed-in tariff of 39.57 cent, a Hamburg household will gain 372 euros annually and a Munich household 452 euros if exporting the whole amount to the grid.

The support programme of the KfW Bank[13] assists PV projects with loans of up to 50 000 euros for private and non-profit users. Installations costing more than 50 000 euros can be financed via the KfW environment and energy-saving programme as well as the KfW environment programme. It is noteworthy that loans from the KfW are not only limited to Germany. They are also available anywhere in the world if the companies involved are German or if the installation is just across the border where the positive impact on the environment will also affect Germany. Up to 100% of the net investment costs can be covered by those programmes by long-term low interest and interest-only loans in the first few years.

Item	Calculation	Total in €
System cost of a 1,5 kWp panel		5000

Energy generated	1500 kWh (per year)	
Price of electricity saved	750 kWh at 15,2 cent	114
Feed-in tariff for sale of energy	750 kWh at 39,57 cent as of 2010	+ 297
Total income and savings, i.e. value of system per year		= 411

Repayment of system cost to householder	5000/411	= 12 years

---

[13] The KfW Bank is a German government-owned development bank. Its name originally comes from Kreditanstalt für Wiederaufbau, meaning Reconstruction Credit Institute and was formed after World War II as part of the Marshall Plan.

3.2.3 An example from the Netherlands

The Netherlands do not have feed-in tariffs yet but there is an incentive scheme for sustainable energy production (Stimuleringsregeling Duurzame Energieproductie SDE) which unfortunately seems to be a lottery. One cannot rely on getting the grant, the chances of succeeding are more or less 50/50 and there seem to be no clear criteria. Furthermore, the subsidy within the incentive scheme varies as well.

One kWp solar panel costs roughly 3500 euros including VAT but excluding installation which would be another 500 per kWp. So in total a complete installation of 1,5 kWp costs 6000 euros. There are other additional costs involved for a system with an SDE subsidy. These are the installation of a compulsory extra meter which measures the kW electricity used and an additional circuit. The irradiation and thus the energy output is similar to a system in the south of the UK. With the incentive scheme it takes around 12.5 years for the system to pay back, without the scheme this increases to 20 years.

In November 2009, the Dutch Cabinet agreed to follow the German example and to implement some parts of the German scheme in the near future in order to encourage investments in green energy. It awaits to be seen whether the fine words on fostering solar energy in the Netherlands will be translated into action.

4. Conclusions:

This paper shows that PV panels do make sense from an environmental point of view. It is clear that PV panels produce at least three times their embedded energy during their life times. If means can be found to enable large-scale recycling of PV components which have come to the end of their useful life, this will increase.

Silicon-based PV modules do not raise concerns in relation to the availability of any key raw materials. If thin-film panels such as CdTe technology were widely adopted there is a question as to whether supply and perhaps more significantly, total available resources could meet such demand.

The factor holding back the widespread deployment of PV technology is the economic costs of the systems. In order to meet the imperative of energy security and climate change concerns, these have to be reduced through political and fiscal means in order to speed up the process sufficiently. There is therefore a need for greater incentives to promote widespread adoption of panels for domestic use. However, political tendencies seem to go in the opposite direction: feed-in tariffs go down every year with the aim of encouraging quick action; and fiscal support is uncertain as many European governments envisage cutting down on the support of PV installations. To cut a long story short: if after having examined the various choices of renewable energy sources you have decided on PV panels, then the best time for purchasing a PV panel is now, whilst prices are at reasonable levels and political incentives are still available.

5. Policy Recommendations:

- The EU must strive to harmonise incentives such as feed-in tariffs across the Member States by following best practices in order to provide a stable and clear operating environment for producers and consumers

- There is a need to incentivise small scale renewable energy production

- Member States must ensure that their domestic tax policies include grants or a system of tax relief for the installation of PV technology in the domestic market

- The EU must ensure that the Buildings Directive includes strong incentives for home builders to include PV technology for new buildings with favourable conditions

- The EU must continue to fund research and development in the PV sector under the 7th Framework Programme and beyond to ensure innovation and to improve competitiveness

- Member States must ensure that public spending constraints do not impact negatively on the incentives for renewable energy production through PV technology

6. Going further - glass art with photovoltaics

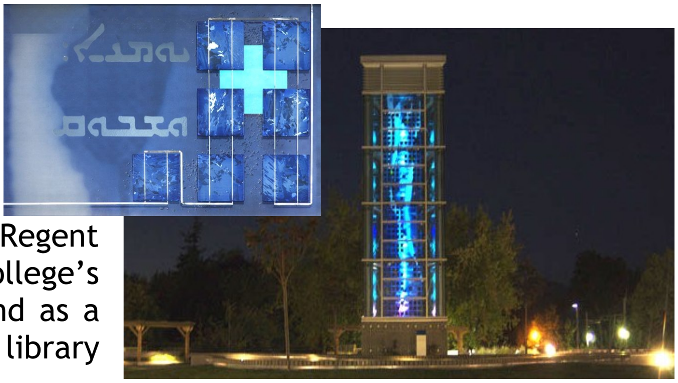
A very innovative way of combining electricity production with artwork and design has been suggested by Sarah Hall, a Quaker, and her art studio in Canada.

Stained glass artists Sarah Hall, RCA is renowned for pioneering imaginative projects. Her work has received numerous awards for outstanding contemporary art and includes some of the largest stained glass projects in Canada and the US. A recent development in her work is the integration of photovoltaic elements into her art glass.

> “Stained glass has a thousand-year history. Using solar energy is one way of bringing new technology to an art form that most people consider traditional and unchanging. However, tradition is not for keeping the ashes – but the fire alive. By forging art with a source of energy we create a powerful image of how we can live in this world.”
>
> *Sarah Hall*

The stained glass with PV is the central element of the Regent College wind tower at the University of British Columbia/ Vancouver

With the *Lux Nova* glass design for a wind tower at Regent College on the University of British Columbia campus in Vancouver, Sarah created the first permanent installation of photovoltaic glass art in North America. The forty-foot triangular aerodynamic glass tower completed the new theology library at the Regent College. It serves as a symbol of the college's commitment to environmental sustainability and as a natural ventilation system for the underground library which opened in September 2009.



The Regent College wind tower by night -
a beacon for the surrounding park

The magnificent *Lux Nova* art glass work is integrated into the south face of the tower: a luminous column of silvery, fused and etched glass. Incorporated in this column are the solar cells that collect energy during the day and use it for night-time illumination.

Solar energy in glass art can illuminate
the interior of a room at night

Solar cells can transform a glass façade into a clean, long-lasting energy source. Sarah has been inspired to incorporate those cells into her art glass by the energy-collecting façades she saw in Europe. On her website www.sarahhallstudio.com she explains the process of integration PV into stained glass: "The solar cells are embedded between two panes of glass which have exceptionally high light transmittance and which have been heat-strengthened. The geometric arrangement and spacing of the solar cells is designed and integrated into the artwork itself, giving varying degrees of transparency and sun-shading."[14]

It is certainly to Sarah's credit that stained glass art is not limited to purely artistic purposes any more but has acquired an environmental sustainability dimension. She is paving the way for a more responsible society where art and design and cutting edge technology merge for the sake of environmental sustainability.

---

[14] http://www.sarahhallstudio.com